ROTSE Survey for Supernovae & Other transients

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ROTSE Collaboration

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See also posters by R. Quimby, S. Yost

Transient Universe 2006 Workshop

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See Rykoff, et al., 2006, ApJ 631, 1032

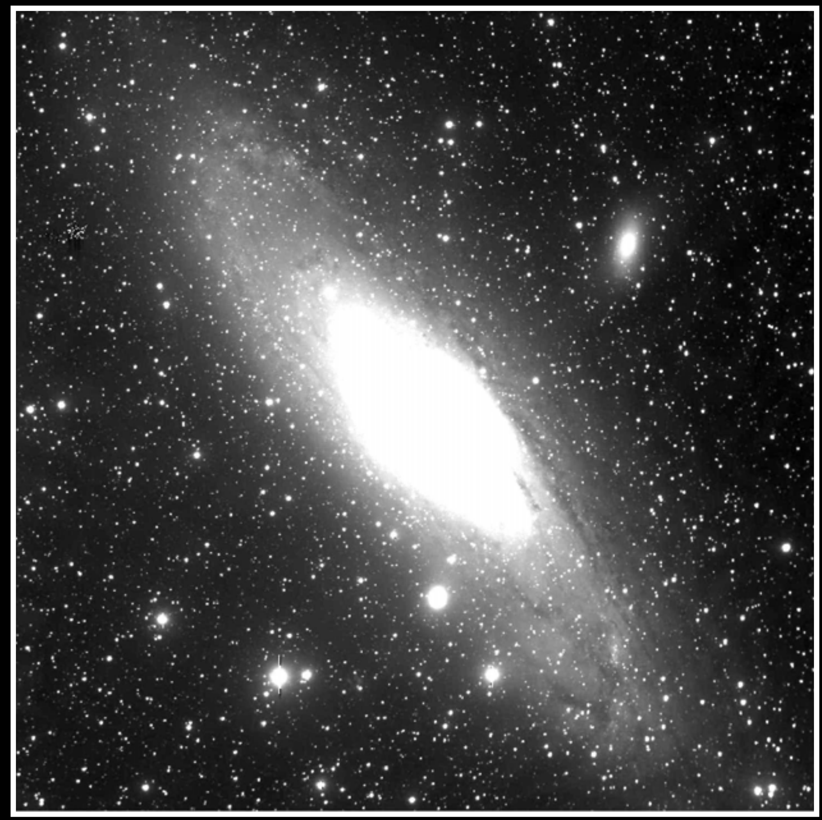
Outline

- Robotic Optical Transient Search Experiment (ROTSE-III) Telescope Systems
- Orphan & Untriggered GRB Afterglows
- The ROTSE-III Search
- Results
- Search for Nearby Supernovae in Virgo
  - R. Quimby, U. Texas
- Conclusions

ROTSE-III Specifications

- 0.45 m telescopes
- 1.85° x 1.85° field (f/1.9)
- Unfiltered 2k x 2k CCD
- Fast (6 s) readout
- ~ 40 deg/s max. slew speed
- Built for *rapid* response to GRB triggers
- Median GRB alert response time is 7 seconds
- All automated, no human intervention

M31 - Andromeda Galaxy



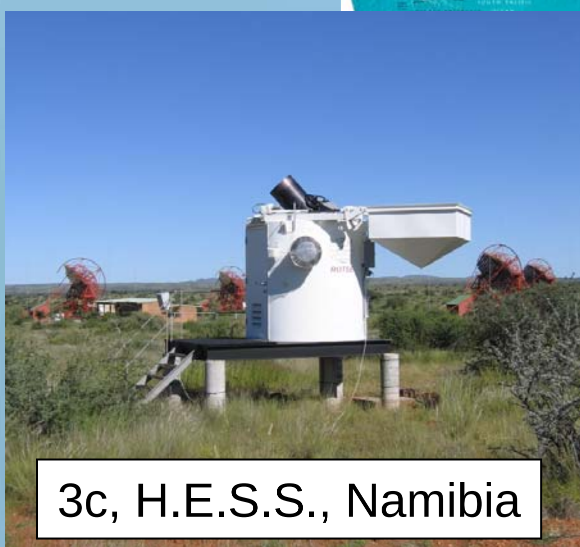
ROTSE-IIIb

ROTSE-III Worldwide

3b, McDonald, Texas

3d, TUG, Turkey

The Sun Never Rises on the ROTSE Empire



3c, H.E.S.S., Namibia

3a, SSO, Australia

Untriggered GRB Afterglows

- Untriggered GRBs
  - Even if a satellite doesn’t detect it, there are ~ 2 GRBs/day visible to the earth
  - Advantage: We know what these optical afterglows look like
  - Disadvantage: Rare
- Orphan GRB Afterglows
  - After the jet break, afterglows should be visible off axis
  - Advantage: Rate might be > 200/day
  - Disadvantage: We don’t know what they look like

Untriggered GRBs

- Search designed to look for untriggered GRBs
  - We know what we're looking for
- How much coverage is required?
  - 2 GRBs/day visible to earth (from BATSE)
  - ~ 50% with visible afterglows
  - 1/day/40000 $\text{deg}^2 \rightarrow$
  - ~ 110 $\text{deg}^2 \cdot$ yr effective coverage required
- Search strategy to have as much coverage as possible

Search Parameters

- Limiting magnitude of ~18.5 determines how long we can see a typical afterglow
- Rapid identification for follow-up
  - Can get spectra while transient is still bright
- Search equatorial stripe covered by SDSS for deep, 5 band background images

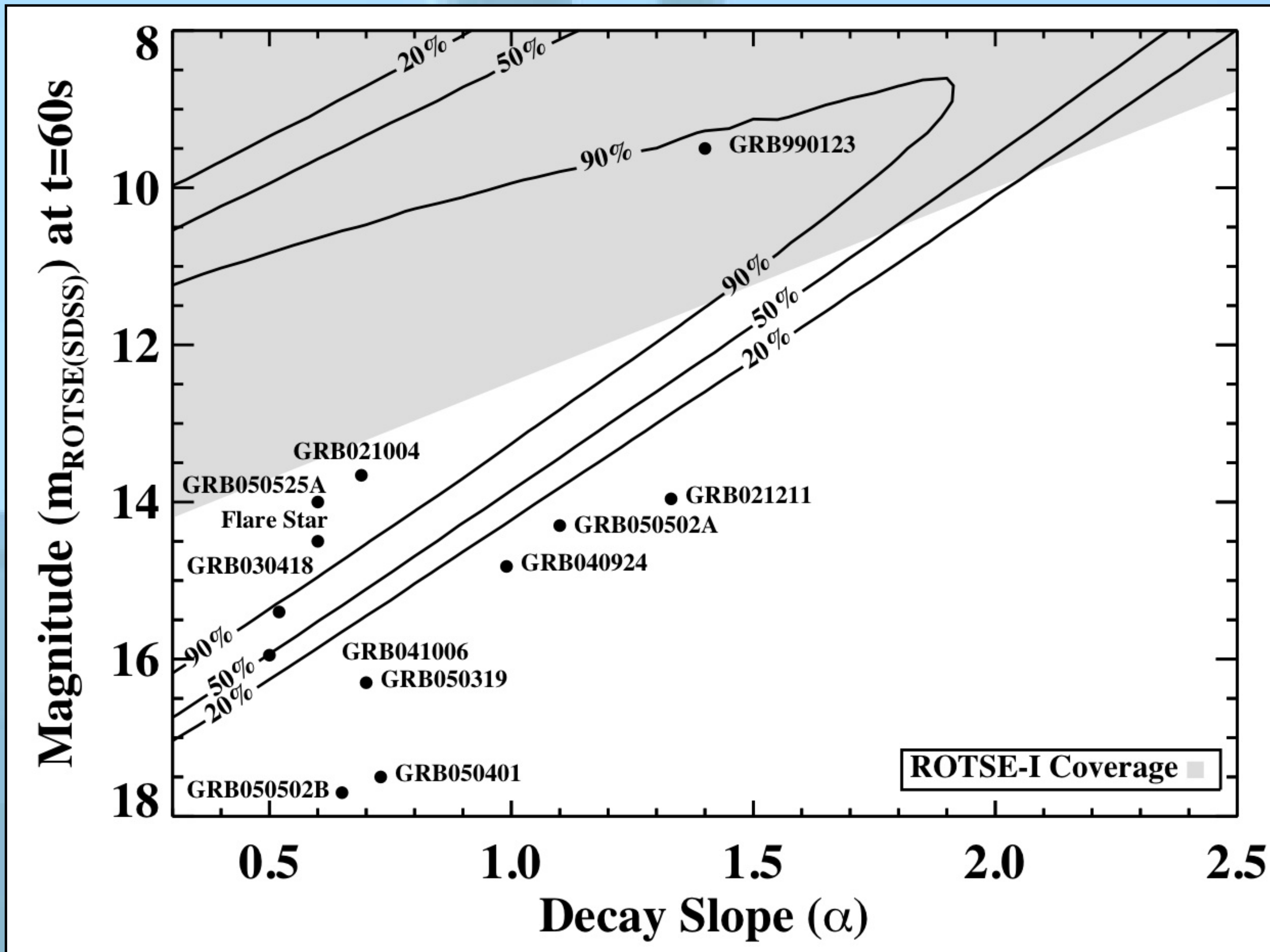
Search Strategy

- Take pairs of images, each pair separated by 30 minutes
  - Pair reduces chance of hot pixel “transients”, cosmic ray coincidences, etc.
  - Effective coverage time is 30 minutes, assuming a typical afterglow is brighter than our limiting magnitude for ~ 1 hour
- A transient candidate must be a new object not detected in four images
  - Efficiency is > 80% for most fields
  - Not sensitive to objects with bright counterparts, eg flares from bright stars

Results

- Through March 2005, covered 1.74 $deg^2 \cdot yr$ with limiting magnitudes better than 17.5
  - Four telescopes operational from May 2004
  - Search is ongoing
- Found
  - Four new cataclysmic variables
    - All with faint ($m_R > 20$) counterparts
    - Rykoff, et al (2004), IBVS 5559; Rykoff (2005), ATel 403; Rykoff (2005), ATel 423
  - One flare star
  - Two supernovae from dwarf galaxies
    - 2005cg, 2005ch
  - No unidentified transients
  - And many, many rocks
    - We avoid low ecliptic latitudes to reduce the number of asteroids

Results



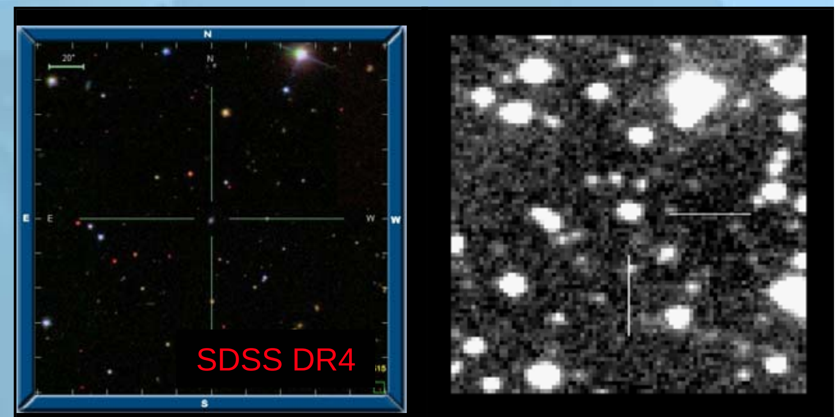
- Sensitive to ~ 50% of typical afterglows

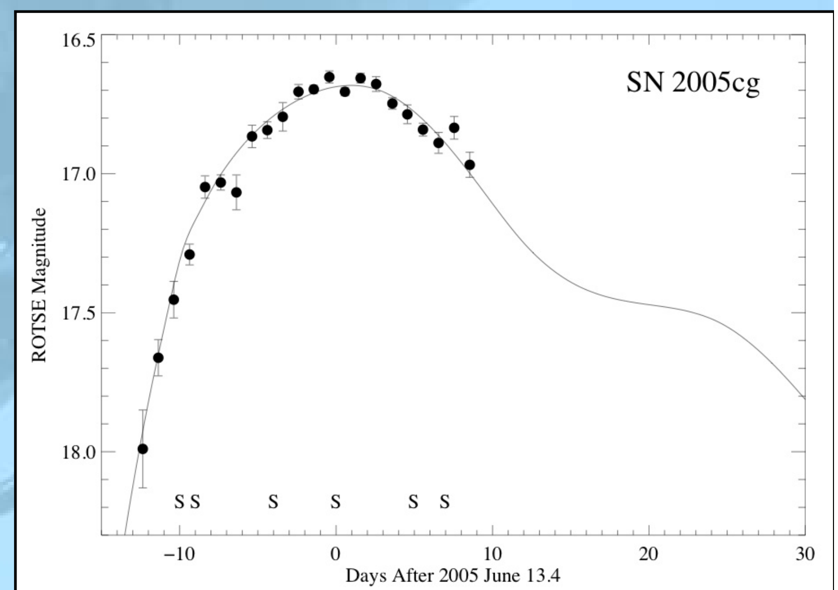
Are GRBs "Spherical Fireballs"?

- Assume GRBs are "spherical fireballs" -- the optical emission is not beamed, but the γ-ray emission is
- From BATSE rate, if we have a double jet, the number of observable bursts is $\sim 1500/\theta_{max}^2$ events/yr
- Our untriggered afterglow rate is < 78000 events/yr (95% confidence)
  - $\Theta_{max} > 3.6^{o}$
- Similar to opening angles determined via standard methods
- Optical emission must be beamed

Supernovae from Dwarf Galaxies

- June 2005 found two supernovae
  - Dwarf galaxy hosts
    - Selection bias
- 2005cg, 2005ch, each Type Ia, z ~ 0.02
- Blind search has implications for high-z supernovae





Quimby et al, 2005

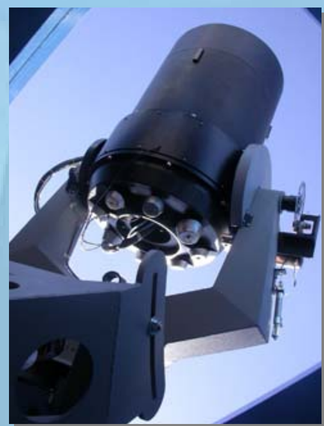
Texas Supernova Search

R. Quimby et al. (U. Texas)

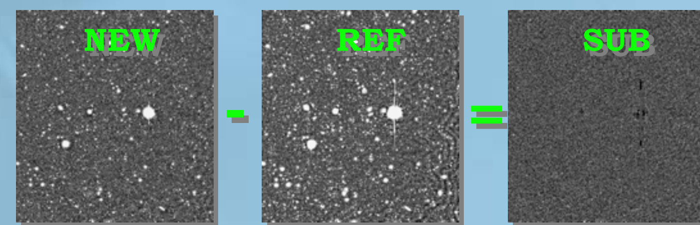
- Goal: To discover and spectroscopically follow the youngest possible supernovae
- Nightly observations cover 1000's of galaxies
  - Virgo, Ursa Major, and Coma clusters
- Image subtraction in near real-time
- Limiting mag ~ 18, can catch a Virgo supernova in 1-2 days from time of explosion

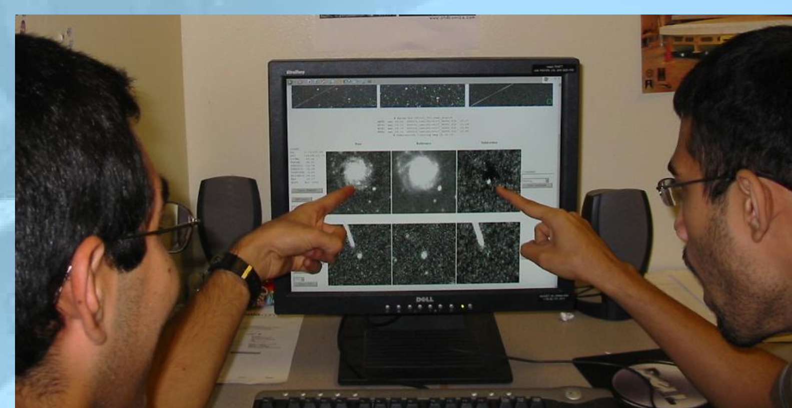
TSS Reduction Pipeline

ROTSE-IIIb (McDonald Observatory) observes targeted fields



Dedicated computer subtracts PSF matched reference template from the new image

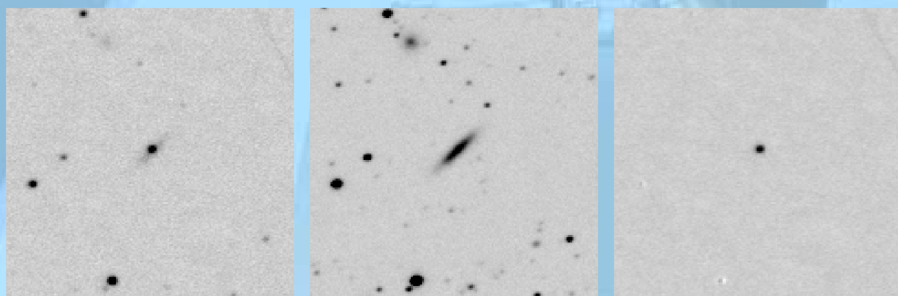




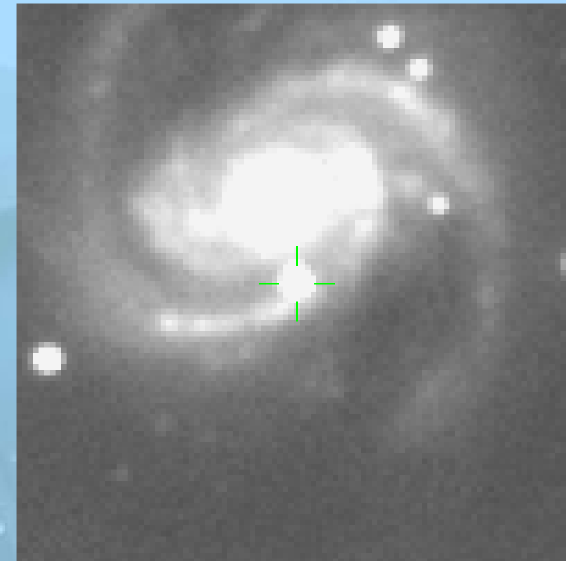
Undergraduates review flagged candidates at U. Texas

SNe candidates observed with 9.2m HET low res spectrograph the same or following night.

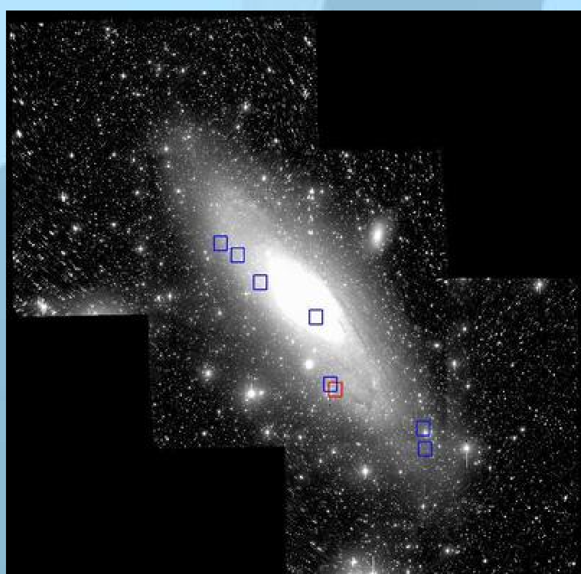
TSS Discoveries



First supernova, 2004gk (Type Ic)



SN 2006X in M100 (first reported by S. Suzuki and CROSS)

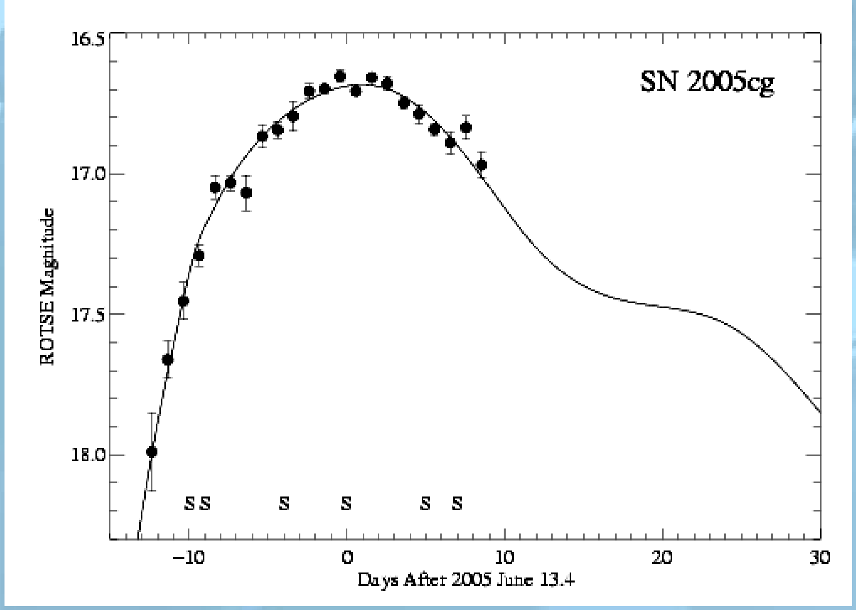


Locations of the 7 novae and 1 LBV discovered in M31

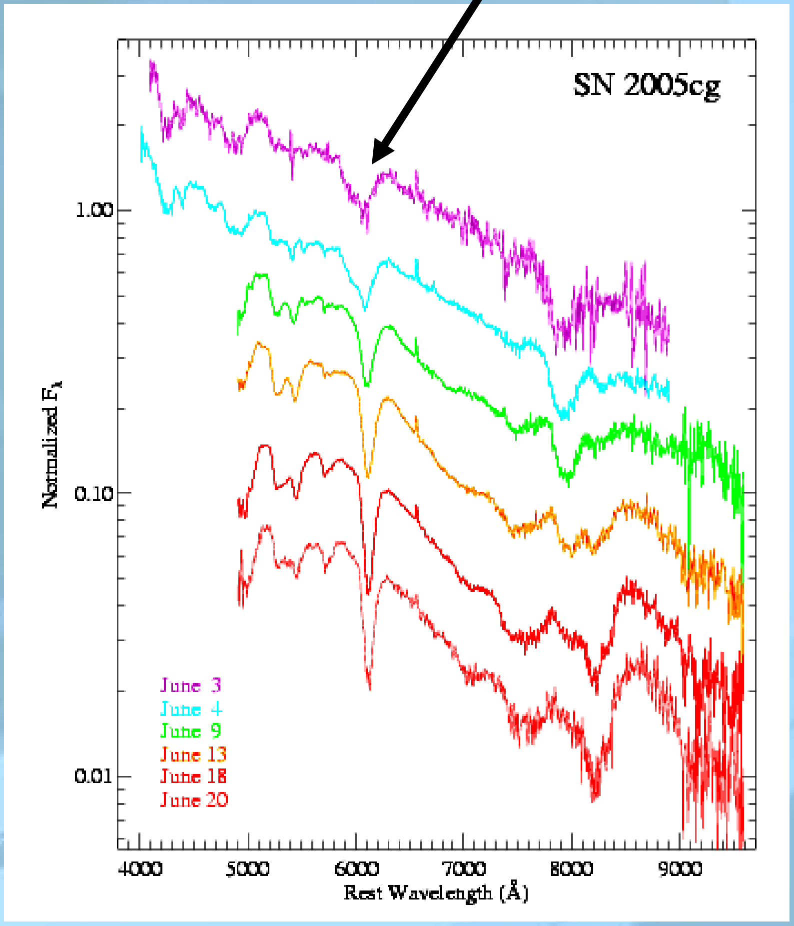
- Discovered 14 SNe + 2 first reported by others (9 Type Ia, 3 Tyle Ic, 3 Type II, 1 Type I?)
- 7 novae and 1 LBV in M31
- 4 dwarf novae
- Lots of bright variable stars

TSS First Results

- SN 2005cg (found by ROTSE-III transient search with ROTSE-IIIc)
- Early HET spectra show high velocity SiII and CaII IR
- Evidence for a detonation phase in a normal SNe Ia.



High velocity SiII



Quimby et al. 2006, ApJ 636, 400

Conclusions

- Achieving the necessary coverage to detect untriggered GRB afterglows is difficult
- Orphans are not as bright as on-axis optical afterglows
- There are not a lot of unknown transients that get brighter than 18^{th} magnitude
- Many low-redshift supernovae from dwarf galaxies are missed by targeted searches
- TSS is discovering nearby SNe and obtaining early spectra

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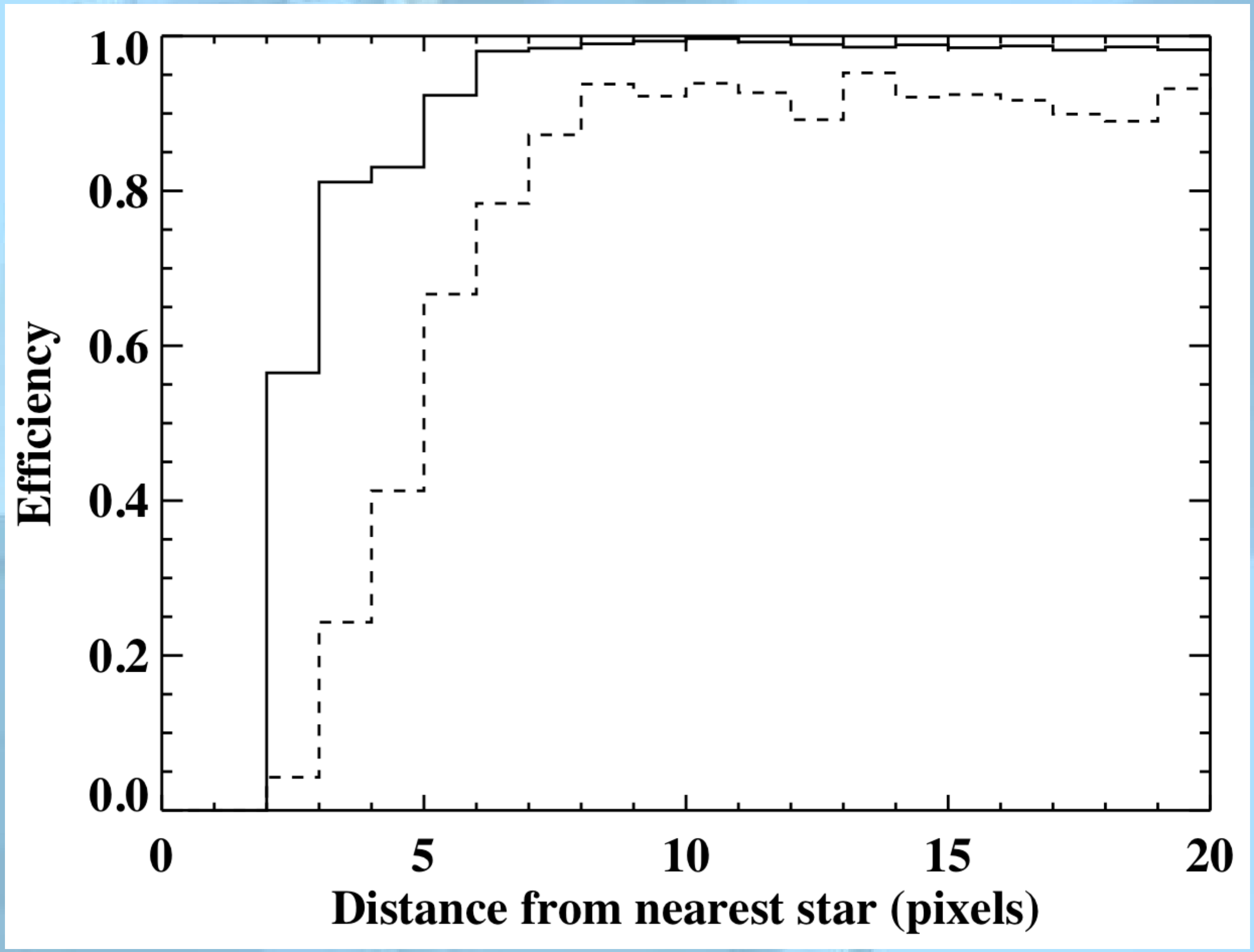
Efficiency



- Efficiency vs. distance from nearest star
- Typically 80% efficient